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TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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A SUMMARY OF RESULTS OF VARIOUS INVESTIGATIONS OF THE
MECHANICAL PROPERTIES OF ALUMINUM ALLOYS
AT LOW TEMPERATURES

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FOR REFERENCE

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A SUMMARY OF RESULTS OF VARIOUS INVESTIGATIONS OF THE
MECHANICAL PROPERTIES OF ALUMINUM ALLOYS
AT LOW TEMPERATURES

By E. C. Hartmann and W. H. Sharp

SUMMARY

The available sources of data on the mechanical properties of aluminum alloys at low temperatures are listed and a summary of the material to be found in each source is given. There is included a discussion of the results of recent tests of aluminum alloys at low temperatures made at the Aluminum Research Laboratories.

SOURCES OF DATA

1. Cohn, L. M.:
Elek. u. Masch., Änderungen der physikalischen,
vol. 31, May 1913 Eigenschaften von Aluminium
und dessen Legierungen unter
besonderer Berücksichtigung
des Duralumins.

Tests of an alloy of the duralumin type in which CO₂ snow was used as the cooling medium gave the following results:

Temperature (°F)	Tensile strength (lb/sq in.)	Elongation (percent) (1)
70	62,400	20.0
-110	67,300	22.5

¹Gage length not given, probably 11.3 \sqrt{a} .

2. Sykes, W. P.:

Trans. Am. Inst.
Mining and Metallur-
gical Eng., vol. 64,
1920, pp. 780-814

Effect of Temperature, Deformation, Grain Size, and Rate of Loading on Mechanical Properties of Metals.

This paper describes the tests of an aluminum alloy containing 3 percent copper, 0.42 percent iron, and 0.21 percent silicon in the form of wire 0.025 inch in diameter. The results were as follows:

Temperature (°F)	Tensile strength	
	Annealed wire (lb/sq in.)	Cold-drawn wire (lb/sq in.)
77	23,000	50,000
-300	37,000	63,000

3. Anon:

Reports of the Light
Alloys Sub-Committee.
Rep. No. 6, British
A.C.A., 1921, pp. 91-
106

Report of the Effect of Low Temperature on Some Aluminum Casting Alloys.

The following paragraph is quoted from the summary of tests made at the National Physical Laboratory in England. Sand-cast and chill-cast aluminum alloys of the types commonly used during the World War (1914-18) for aircraft-engine castings were used in these tests.

"The results of the tests indicate clearly that there is no marked decrease in the strength of any of these alloys when they are exposed to low temperatures, either while

the alloys are at the low temperatures or when they are subsequently allowed to regain ordinary temperatures. On the contrary, it is found that at these low temperatures the alloys are markedly stronger, but that the strength becomes normal when they are again raised to ordinary atmospheric temperature."

4. Guillet, Léon, and
Cournot, Jean:
Revue de Métallur-
gie, vol. XIX, no.
4, April 1922,
pp. 215-221

Sur la variation des propriétés
mécaniques de quelques métaux
et alliages aux basses tem-
pératures.

Hardness and impact tests
made on a duralumin type alloy
with liquid air as the cooling
medium gave the following re-
sults:

Temperature (°F)	Brinell hardness number	Impact resistance of Mesnager specimen in Guillery machine (ft-lb)
68	101	5.0
-310	129	5.6

5. Strauss, J.:
Trans. Am. Soc.
Steel Treating,
vol. 16, no. 2,
Aug. 1929, pp.
191-226

Metals and Alloys for Indus-
trial Applications Requiring
Extreme Stability.

Tensile tests on duralumin,
in which liquid air was used as
the cooling medium, gave the
following results:

Temperature (°F)	Tensile strength (lb/sq in.)	Yield strength (lb/sq in.)	Elongation in 2 in. (percent)	Reduction of area (percent)
70	57,000	35,400	26.5	27.0
-310	71,800	42,700	28.0	28.7

6. Schwinning, W., and
Fischer, F.:
Zeitschr. f. Metall-
kunde, Bd. 22, No. 1,
Jan. 1930, pp. 1-7.

Versuche über den Einfluss
der Temperatur auf Korb-
zähigkeit und Härte von
Aluminiumlegierungen.

Report on hardness and
impact tests on notched bars
of Lantal and 99.5 percent
aluminum. The following
table summarizes the results:

Alloy	Temperature (°F)	Brinell hardness number	Impact strength (m-kg/cm ²)
99.5 percent aluminum	68	30.4	4.0
	-105	36.0	-----
	-306	-----	6.1
Lantal	68	110.0	1.5
	-105	115.0	-----
	-306	-----	1.7

7. Guldner, W. A.:
Zeitschr. f. Metall-
kunde, Bd. 22, No. 8,
Aug. 1930, pp. 257-
260.

Über die Korbzähigkeit
einiger Aluminiumlegierungen
insbesondere bei tiefen
Temperaturen.

This author found improve-
ment in the impact behavior of
a few aluminum alloys at
-75° F.

8. Pester, Fr.:
 Zeitschr. f. Metallkunde, Bd. 22, No. 8, Aug. 1930, pp. 261-263
 Die Festigkeitseigenschaften von elektrischen Leitungsdrähten bei tiefen Temperaturen.

Pester found increases in tensile strength for aluminum conductor wire at -76° F.

9. Templin, R. L., and Paul, D. A.:
 Symposium on Effect of Temperature on the Properties of Metals, issued jointly by A.S.T.M. and A.S.M.E. 1931
 Mechanical Properties of Aluminum and Magnesium Alloys at Elevated Temperatures.

Tests made at the Aluminum Research Laboratories on various aluminum alloys cooled in a mixture of solid CO_2 and ether gave the following results:

Alloy	Temperature ($^{\circ}$ F)	Tensile strength (lb/sq in.)	Yield strength (lb/sq in.) (1)	Elongation in 2 in. (percent)
2S0	70	13,250	4,150	41.5
	-110	15,180	4,150	47.5
2SH Rod	70	23,460	19,700	16.0
	-110	24,720	21,350	18.0
3SH Rod	70	28,730	25,300	10.0
	-110	31,940	28,200	12.5
17S-T Rod	70	68,000	45,500	15.0
	-110	70,000	46,500	16.0
No. 43 sand cast	70	20,050	8,000	4.5
	-110	20,180	8,000	5.0
No. 195-4 sand cast, heat treated	70	35,145	23,250	4.5
	-110	36,830	25,200	4.0

¹Offset = 0.1 percent.

10. Matthaes, K.:

Zeitschr. f. Metallkunde, Bd. 24, No. 8, Aug. 1932, pp. 176-180

Dynamische Festigkeitseigenschaften einiger Leichtmetalle.

This author found increases in impact strength for some aluminum alloys at -110°F and no change from room temperature values at -290°F .

11. Johnson, J. B.,

and Oberg, Ture:
Metals and Alloys,
vol. 4, no. 3,
March 1933, pp. 25-30

Mechanical Properties at Minus 40 Degrees of Metals Used in Aircraft Construction.

In tests made in the mechanically refrigerated cold room at Wright Field, duralumin rod and forgings showed the following results:

Temperature ($^{\circ}\text{F}$)	Tensile strength (lb/sq in.)	Yield strength (lb/sq in.) (1)	Elongation in 4D (percent)	Izod impact (ft-lb) (2)	Endurance limit (lb/sq in.) (3)
Forging					
70	55,500	30,000	16	13	13,000
-40	58,500	31,500	13	13	16,000
Rod					
70	58,000	42,000	23.0	-----	-----
-40	60,500	44,500	23.5	-----	-----

¹ Offset = 0.2 percent.

² 45 $^{\circ}$ V notch, 0.01-inch radius.

³ Rotating beam, 500,000,000 cycles.

12. Schwinning, W.:
 VDI Zeitschr.,
 Bd. 79, Nr. 2,
 Jan. 1935, pp. 35-
 40

Die Festigkeitseigenschaften
 der Werkstoffe bei tiefen
 Temperaturen.

The results given in this
 paper are tabulated as follows:

Alloy	Tempera- ture (°F)	Tensile strength (lb/sq in.)	Yield strength, set = 0.2 percent (lb/sq in.)	Elonga- tion in 25 cm (percent)	Fatigue strength, 10 ⁶ cycles (lb/sq in.)
Pure aluminum (99.5 percent) hard drawn	68 -40	21,000 23,000	18,600 19,800	14 11.3	12,000 12,800
Aldrey	68 -40	42,000 44,500	37,000 38,000	12.7 11.6	16,000 18,500
Bondur	68 -40	64,000 65,000	48,000 48,400	18.8 19.9	20,000 16,300
Duralumin 681 B	68 -40	61,500 63,000	49,000 49,600	16.9 15.0	18,000 18,000
Duralumin DM31	68 -40	71,000 74,000	57,000 56,000	16.3 17.1	20,000 20,000

13. Boone, W. D.,
 and Wishart, H. B.:
 A.S.T.M. Proc.,
 vol. XXXV, pt. II,
 1935, pp. 147-155

High-Speed Fatigue Tests of
 Several Ferrous and Non-
 Ferrous Metals at Low Tem-
 peratures.

Rotating-beam fatigue
 tests made in the cold room at
 Wright Field on duralumin spec-
 imens indicate the following:

Temperature (°F)	Endurance limit based on 50,000,000 cycles (lb/sq in.)
80	17,000
-40	21,000

14. Moore, H. F.,
Wishart, H. B.,
and Lyon, S. W.;
A.S.T.M. Proc.,
vol. XXXVI, pt.
II, 1936, pp. 110-
117

Slow-Bend and Impact Tests
of Notched Bars at Low
Temperatures.

Tests made on 17S-T
rod in one of the cold rooms
at Wright Field have shown
the following results:

Temperature (°F)	Slow bend tests energy for fracture (ft-lb)	Impact tests energy for fracture (ft-lb) (1)
70	13.00	18.10
-40	13.82	19.60

¹Izod test, specimen with 45° V notch, 0.01-
inch radius.

15. Bungardt, K.:
Zeitschr. f. Metall-
kunde, Bd. 30, No. 7,
July 1938, pp. 235-
237

Dynamische Festigkeitseigen-
schaften von Leichtmetall-
Legierungen bei tiefen
Temperaturen.

Tests made in Germany
on duralumin rod and sheet
showed the following re-
sults:

Temperature (°F)	Endurance limit (lb/sq in.) (1)	Notched bar impact (m-kg/cm ²)
68	23,000	0.96
-85	27,000	1.32

¹Rotating beam machine using
20,000,000 cycles.

16. NACA Annual Reports:
1936, 1937

The Twenty-second and Twenty-third Annual Reports of the National Advisory Committee for Aeronautics comment briefly on a program of tests carried out by the National Bureau of Standards in cooperation with the Bureau of Aeronautics on various aircraft metals at sub-zero temperatures. The program involved what appears to have been an extensive study of properties and impact resistance. The following quotation is taken from the Twenty-third Annual Report, page 32:

"The only important adverse effect of low temperature, down to -80° C [-112° F], is the decreased impact resistance of ferritic steels, which is in marked contrast to the aluminum alloys and the austenitic steels."

17. Rosenberg, Samuel J.:
Res. Paper 1347, Nat.
Bur. of Standards
Jour. Res., vol. 25,
no. 6, Dec. 1940,
pp. 673-701

Effect of Low Temperatures
on the Properties of Air-
craft Metals.

The conclusions of

this report include the following quotation:

"The effect of sub-zero temperatures down to -78°C [-109°F] was determined on the tensile, hardness, and impact properties of metals commonly used in aircraft construction.

"The tensile properties and the hardness of all materials were generally improved at low temperatures. . . . The impact resistance of the aluminum-base alloys was not decreased; . . ."

18. Gillett, H. W.:
Book prepared for
Project 13 of the
Joint A.S.T.M.-
A.S.M.E. Research
Committee on Effect
of Temperature on
Properties of Metals,
Aug. 1941. American
Society for Testing
Materials, Phila., Pa.

Impact Resistance and Tensile Properties of Metals at Subatmospheric Temperatures.

This book summarizes data, both published and unpublished, from numerous sources. Tables 125, 133, and 134 deal specifically with aluminum alloys, and the text, in reference to these tables, states:

"All these non-ferrous alloys are shown to have very closely the same properties at -40°F as at room temperature.

"No deterioration in properties is met at -105°F in these wrought alloys. . . . the determinations at -105°F could be taken as checking the room temperature figures."

TESTS ON SOLID ROUND RODS AT -120° F

In all the foregoing investigations the materials were in the form of small laboratory specimens. In order to demonstrate the ability of the various aluminum alloys to withstand severe shock loads at low temperatures in larger size pieces, a series of tests were made on 2-inch solid round rods subjected to the blow of a 500-pound tup striking at the center of a 36-inch span. All tests were conducted under the outdoor impact test tower at Aluminum Research Laboratories and for the low temperature tests the specimens were cooled to a temperature of -120° F by use of a mixture of dry ice and kerosene. Figure 1 shows the six specimens following the low temperature drop tests. The height of drop used in each case and the permanent sets, both at ordinary temperature and at low temperature, are given in the following table:

Alloy	Height of drop of 500-lb tup (in.)	Permanent set (in.)	
		Rod at 75° F	Rod at -120° F
27S-T	120	$4\frac{5}{8}$	$4\frac{3}{4}$
17S-T	96	$4\frac{1}{8}$	$4\frac{3}{16}$
61S-T	96	$5\frac{1}{4}$	$5\frac{1}{4}$
A17S-T	84	$5\frac{1}{2}$	$5\frac{5}{16}$
53S-T	84	$5\frac{5}{8}$	$5\frac{3}{4}$
52S- $\frac{1}{4}$ H	72	6	6

CONCLUSION

On the basis of the foregoing test results, it can be concluded that aluminum alloys, in general, either remain unchanged or show an improvement in strength and ductility when exposed to low temperatures.

Aluminum Research Laboratories,
Aluminum Company of America,
New Kensington, Pa., December 10, 1941.

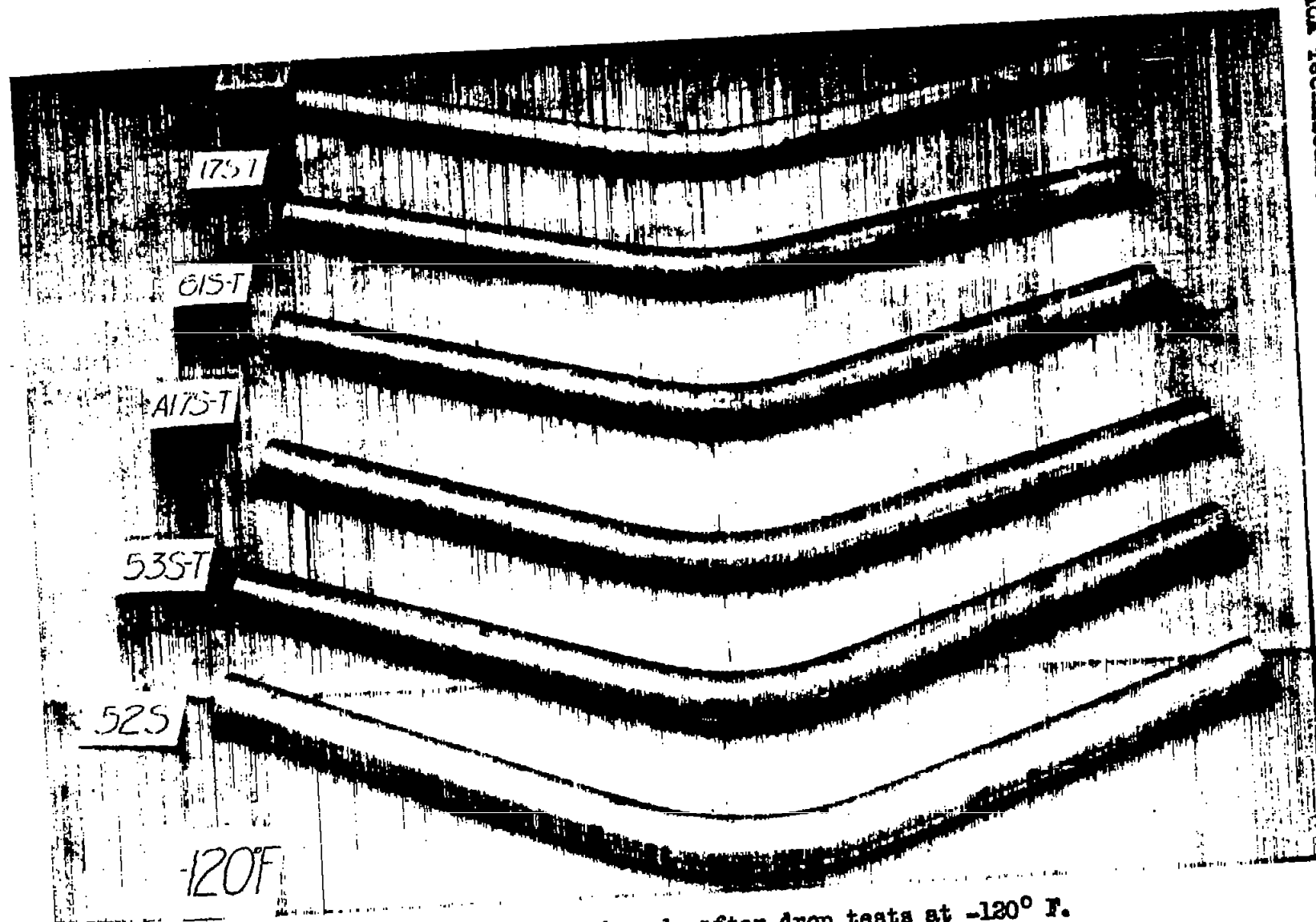


Figure 1.- The 2-inch rods after drop tests at -120° F.